Time Hopping QPSK Impulse Signal Transmission for Ultra Wideband Communication System in the Presence of Multipath Channel

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***Abstract*—New ultra wideband (UWB) communication system using quadrature-phase shift keying (QPSK) impulse modulation with time-hopping (TH) multiple-access scheme is proposed. The simulation results in multipath channel show that the proposed UWB communication system can provide better performances compared with conventional TH-PPM UWB communication system.**

I. INTRODUCTION

Ultra wideband (UWB) technology is a major candidate for a high data rate personal wireless area network (PWAN) since the Federal Communications Commission (FCC) has allocated a UWB spectrum in February 2002 [1]. Time hopping multiple access system with pulse position modulation (TH-PPM) [2] is an original idea for UWB communication systems using an impulse radio signal. The capacity of TH-PPM UWB system in an additive white Gaussian noise (AWGN) channel for voice communication is about 27500 users with bit error rate (BER) of 10^{-3}. More studying in UWB systems [3]-[6] are investigated. Actually, inter symbol interference (ISI) caused by multipath channel is a major degradation parameter to the performance of UWB communication systems [7]. Moreover, the radiated signals from other concurrent users can produce multiple access interference (MAI) to a given user. Thus, the received signal is attenuated and distorted by path loss, multipath components, MAI, and AWGN.

In order to enhance transmission bit rate, more complex modulation than binary modulation must be applied. Thus, in this paper, we introduce new quadrature phase-shift keying (QPSK) impulse modulation for UWB communication system with TH multiple-access scheme. TH-QPSK UWB system compiled with FCC's spectrum definition [1] is proposed and its performances in multipath channel are investigated with the results compared with conventional TH-PPM system.

The organization of this paper is as follows. Section II presents the impulse signals. Section III describes the proposed QPSK impulse modulations including transmitters. Multipath channel model and receivers are in Section IV. The simulation results and discussions are in Section V. Finally, Section VI discusses and concludes the paper.

II. UWB SIGNALS

The diagram of in-phase/quadrature-phase impulse signal generator used in this paper is shown in Fig. 1. The local oscillator is used to generate in-phase and quadrature-phase sinusoidal signals having center frequency at f_c Hz. FCC defines the bandwidth of UWB signal for communication system from 3.1 to 10.6 GHz and its spectrum power density is less than –41.3 dBm/MHz. To follow the FCC's spectrum definition, the sinusoidal signals are shaped with shaping function for deriving impulse signals. The shaping function is used to shape the signal's spectrum.

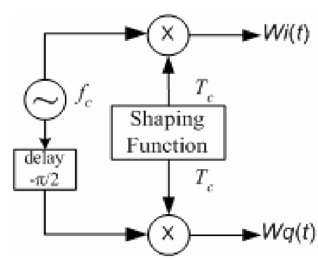

Fig. 1. Impulse generator.

In order to generate a signal with wideband spectrum, the Gaussian pulse is used to be a

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shaping function. Fourier transform of Gaussian pulse is of course Gaussian spectrum. Thus, the Gaussian shaping function in term of exponential function is

$$I_s(t) = e^{-\varsigma B_f^2 f_c^2 t^2} \quad ; -T_c/2 \le t \le T_c/2 \qquad (1)$$

where B_f is a half fractional bandwidth, T_c is a chip duration, and ζ is a shaping factor coefficient. Normally, the decreasing rate of slope of shaped signal's spectrum is characterized by ζ, B_f, and f_c. However, only the shaping factor coefficient can be changed. Thus, the in-phase and quadrature-phase impulse signals can be written as

$$w_i(t) = I_s(t)\cos(\omega_c t) \text{ and } w_q(t) = I_s(t)\sin(\omega_c t), \quad (2)$$

respectively. The lower and upper cutoff frequencies of the FCC's spectrum definition are about 3.1 and 10.6 GHz, respectively. Then, the center frequency and half fractional bandwidth are about 6.8 GHz and 0.544, respectively. To comply with FCC's spectrum definition, the value of ζ is 4. The in-phase, quadrature-phase impulse signals, and their combinations are plotted as shown in Fig. 2. The solid lines are the signals in the proposed UWB communication system. The dotted line is the envelope of shaping function. The impulse signals have total duration of about 0.58 ns.

III. TRANSMITTER

In order to improve the transmission bit rate and system performance, in-phase and quadrature-phase impulse signals are used to modulate using QPSK scheme for various multiple access schemes.

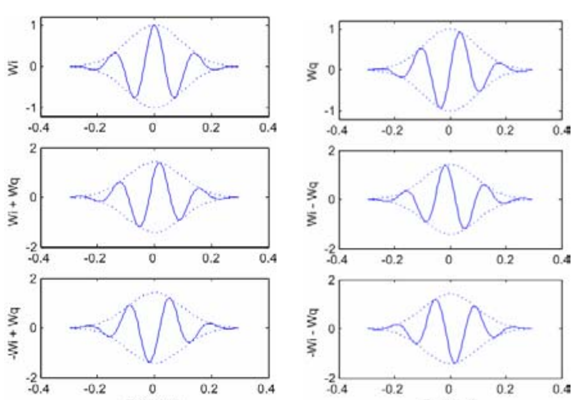
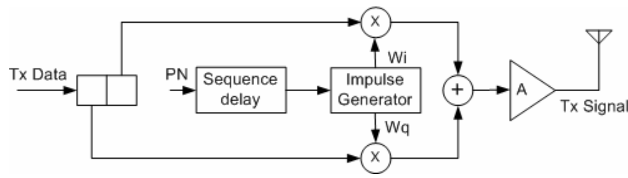
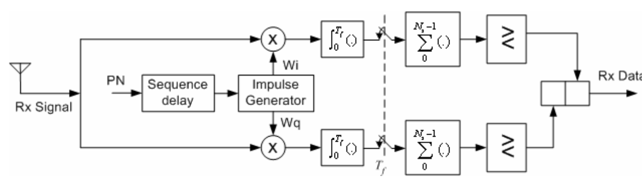


Fig 2. In-phase and quadrature-phase impulse signals and some of their combinations.

The representative diagram of TH-QPSK UWB transmitter is shown in Fig. 3(a). The transmitted signal is processed in the manner of time-hopping scheme with QPSK modulation. Two input data bits are separately modulated with in-phase and quadrature-phase impulse signals, respectively. The impulse signals are generated by impulse generator as shown in Fig. 1. However, both signals are coded into time slot using the same coding sequence. The coding sequence can be derived from a PN generator. Then the signals multiplied by impulse signals are combined and amplified before transmission. It is noticed that the transmitter structure of TH-QPSK is very simple.



(a) Transmitter



(b) Receiver

Fig. 3. The proposed system.

The transmitted signal of TH-QPSK UWB communication system for the kth user is

$$s^k(t) = A\sum_{j=-\infty}^{\infty}[b^{k,1}_{\lfloor j/N_s \rfloor} w_i(t - jT_f - c_j^k T_c) + b^{k,2}_{\lfloor j/N_s \rfloor} w_q(t - jT_f - c_j^k T_c)] \qquad (4)$$

where $b^{(k,1)}$ and $b^{(k,2)}$ are mapping values of the first and second input information bit, respectively, w_i and w_q are in-phase and quadrature-phase impulse signals, respectively, T_f is a frame duration, T_c is a chip duration, $\lfloor x \rfloor$ is truncation function giving an integer of x, N_s is the number of frame per symbol and $\{c^k_j\}$ is a set of time-hopping coding sequence. Thus, each transmitted frame consists of N_h chips and $\max_j(c_j^k) = N_h - 1. = N_h - 1$. The mapping value, b, is of -1/+1.

IV. RECEIVED SIGNALS

Multipath channel is a major factor to decrease the system performances. Channel model proposed by the IEEE802.15.3a working group [7] can provide not only arrival component, but also arrival clusters, taking into account multipath characteristics. The channel impulse response for the kth user can be written as

$$h^{(k)}(t) = \sum_{l=0}^{L}\sum_{h=0}^{H}\alpha_{h,l}^{(k)}\delta(t - T_l^{(k)} - \tau_{h,l}^{(k)}) \qquad (5)$$

where $\alpha_{h,l}^{(k)}$ is the multipath gain coefficient, $T_l^{(k)}$ represents the delay of the lth cluster, and $\tau_{h,l}^{(k)}$ is the delay of the hth multipath component relative to the lth cluster arrival time. The indoor multipath channel parameters for 1-4 meters from the signal source with line-of-sight (LOS) path recommended by the IEEE802.15.3a working group are mainly investigated. The received signal at the input of the proposed receiver in Fig. 3(b) for the kth user can be written as

$$\begin{aligned} r^{(k)}(t) &= s^{(k)}(t)\otimes h^{(k)}(t) \\ &\quad + \sum_{j=0, j\neq k}^{K-1} s^{(j)}(t)\otimes h^{(j)}(t) + n^{(j)}(t) \end{aligned} \qquad (6)$$

where $s(t)$ corresponds to the transmitted signal from TH-QPSK UWB transmitter. The second term is characterized as a multiple-access interference and $n(t)$ is AWGN at the input of receiver. Normally, the received noise has a power of $\eta/2$ and can be represented as

$$n(t) = n_i(t)\cos(2\pi f_c t) - n_q(t)\sin(2\pi f_c t) \qquad (7)$$

where both noise components also have a power of $\eta/2$ and are statistically independent of each other. Thus, the total average power noise is

$$E[n^2(t)] = \frac{1}{2}E[n_i^2(t)] + \frac{1}{2}E[n_q^2(t)]\,. \qquad (8)$$

The received signal is first multiplied by in-phase and quadrature-phase impulse signals generated by the receiver, the same code as generated by the transmitter. Then, the integrators are applied. The MRC are also applied after the sampling process. Thus, signals at the output of MRC are

$$y_i = \sum_{j=0}^{N_s-1}\int_{\tau_s + jT_f}^{\tau_s+(j+1)T_f} r(t)w_i(t-\tau_s - jT_f - c_jT_c)dt \qquad (9)$$

and

$$y_q = \sum_{j=0}^{N_s-1}\int_{\tau_s + jT_f}^{\tau_s+(j+1)T_f} r(t)w_q(t-\tau_s - jT_f - c_jT_c)dt \qquad (10)$$

for in-phase and quadrature-phase components, respectively. The received information bits can be obtained by using sign detection of (9) and (10).

V. SIMULATION RESULTS AND DISCUSSIONS

The simulation results of all studied systems are based on 100 realizations of 1,000 information bits. The parameters in the simulation are described in Table I. Moreover, the simulation results compared with those of the conventional TH-PPM UWB system are also conducted.

TABLE I Parameters of TH-QPSK UWB system

N_s (frames/symbol)	1	2
R_b (Mbps)	12.5→200	
Number of bits/symbol	2	
T_f (ns)	160→10	80→5
T_c (ns)*	0.625	
N_h (chips/frame)	256→16	128→8

The simulation results for single user system (K = 1) and multiple user system (K = 5) are shown in Figs. 4 and 5 for the transmission bit rates of 100 and 25 Mbps, respectively. TH-QPSK UWB system can obviously provide better performance than TH-PPM UWB system. It can be noticed from Fig 4(b) that floor of bit error rate for TH-QPSK UWB system disappears. Because TH-QPSK UWB transmitter transmits one impulse signal per frame, ISI due to multipath components from the previous frame do slightly affect the present frame with long frame duration, especially for low transmission bit rate and single user system. Moreover, it can be noticed that the number of frames per symbol does not improve the system performance in multipath channel. In the next simulation results, the comparisons between BER and the number of users at E_b/N_o = 15 dB for R_b = 100 and 25 Mbps are shown in Fig. 6. TH-QPSK UWB system provides better performance than TH-PPM UWB system in all number of users. TH-QPSK UWB system with R_b of 100 Mbps can slightly provide performance worse than TH-PPM UWB system with R_b of 25 Mbps.

VI. CONCLUSIONS

New multiple-access scheme with QPSK modulation for UWB system in the presence of multipath channel has been proposed. The spectrum of the proposed system complies with the FCC's spectrum definition using the proposed impulse signals. The performances for various transmission bit rate of UWB systems have been studied. The simulation results show that TH-QPSK UWB system obviously provides better performance than TH-PPM UWB system. Moreover, TH-QPSK UWB system can transmits higher information bit rate using QPSK modulation compared with TH-PPM UWB system.

The proposed system is theoretically possible because it has simple circuits. However, the practical circuits for wide bandwidth operation need complicated method for implementation. Thus, the implementation of transmitter and receiver for UWB system is an attractive topic in the future works.

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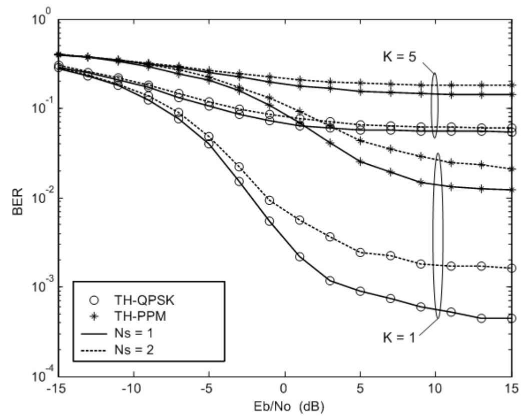

Fig. 4. BER vs Eb/No for R_b = 100 Mbps.

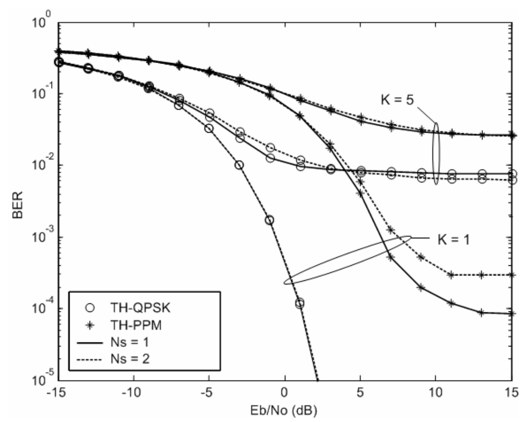

Fig. 5. BER vs Eb/No for R_b = 25 Mbps.

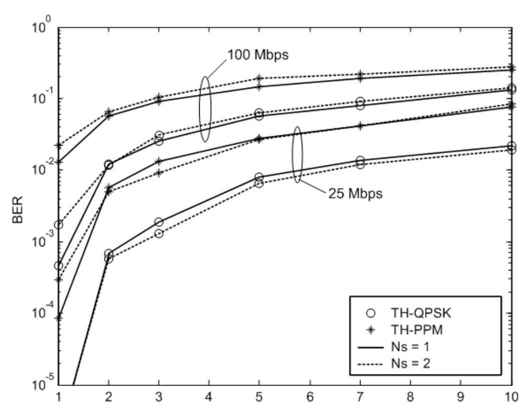

Fig. 6. BER vs number of users for R_b = 25 and 100 Mbps.